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SEA KING MATHEMATICAL MODEL VALIDATION TRIALS. FLIGHT DATA CHANNEL CALIBRATION.

D.T. HOURIGAN

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A

SUMMARY

Thirty two channels of flight data were recorded to validate a mathematical model of an R.A.N. Sea King Mk.50 helicopter. This memorandum describes the calibration procedure for each channel.

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CONTENTS (CONTD.)

1. INTRODUCTION

The 32 flight data channels recorded for the validation of a mathematical model of an R.A.N. Sea King Mk.50 helicopter were calibrated after the looming, transducers and the A.D.F. D.A.S. were installed in the aircraft.

Some channels were calibrated using ground power and hydraulics, some required aircraft engines running and rotor blades turning, and some were calibrated during flight sequences. A fourth group were impracticable to calibrate in the aircraft, so calibrations for these were obtained from manufactures data and known amplifier gains.

In all cases the Data Acquisition System (D.A.S.) tape recorder was recording data whilst the input signal was varied over its operating range and immediately after the recording was reconstructed in analogue form and displayed on a C.R.O. or as a digital voltage on the digital voltmeter (D.V.M.) of the D.A.S. quick look (Q.L.) facility.

This memorandum (i) briefly outlines the procedures followed to calibrate each channel, (ii) illustrates the method of using special calibration jigs, and (iii) tabulates calibration values obtained during the July-August 1979 trials installation.

2. CHANNELS CALIBRATED USING GROUND POWER AND HYDRAULICS

2.1 Cyclic Pitch

An inclinometer was attached to the cyclic control so as to measure angles in the for-aft direction. With the collective control fully down the cyclic control was centralised for roll, then moved from the fore to the aft position. At selected positions, measurements were made of stick angle with the inclinometer, and rotor blade pitch angle over the for-aft servo jack with the rigging protractor. With the D.A.S. operating the quick look D.V.M. displayed the outputs of the for-aft cyclic control linvar channel, and the auxilary (aux.) servo for-aft push pull rod channel. A measurement of displacement of the aux. servo for-aft push pull rod was made at each position.

The collective control was fully raised and the measurements were repeated with the cyclic control at the fully forward and fully aft positions to determine any collective to pitch cross coupling.

2.2 Cyclic Roll

The inclinometer was rotated so as to measure angles of the cyclic control in the lateral direction. With the collective control fully down and the cyclic centralised in pitch, the cyclic was

varied from full port to full starboard (STB). At selected positions measurements were made of stick angle with the inclinometer and rotor blade pitch angle over the port lateral servo jack with the rigging protractor. With the D.A.S. operating the O.L. D.V.M. displayed the outputs of the cyclic control roll linvar channel and the aux. servo lateral push pull rod channel. A measurement of displacement of the aux. servo lateral push pull rod was made at each position.

The collective control was fully raised and the measurements were repeated with the cyclic control at the port and starboard extremes to determine any collective to roll cross coupling.

2.3 Collective Pitch

The inclinometer was attached to the co-pilots (left hand side) collective control to measure the angles as the control is raised or lowered. The cyclic controls were centralised in both pitch and roll, and the collective was raised from the lowered position. At a number of selected positions measurements were made of collective stick angle with the inclinometer and rotor blade pitch angle over the for-aft servo jack with the rigging protractor. The O.L. D.V.M. displayed the outputs of the collective stick transducer channel and the aux. servo collective push pull rod channel. A displacement measurement of the aux. servo collective push pull rod was made at each position.

2.4 Yaw Pedal

The cyclic control stick was centralised in both pitch and roll and the collective control stick set at mid range. The port yaw pedal was depressed to its extremity, then the starboard pedal progressively pushed forward. At a number of selected steps measurements of displacement were made of the pedal and the aux. servo yaw push pull rods. The tail rotor blade pitch angles were measured at the two vertical positions using the tail rotor rigging protractor. The outputs of the yaw pedal coupling rod transducer channel and the aux. servo yaw push pull rod channel were displayed on the O.L. D.V.M. at each step.

The above measurements were repeated with the collective control lever fully down then fully raised, so that any collective to yaw cross fed could be determined.

2.5 Pitch Vane

The vane alignment jig was attached to the body of the Pitot Static (P.S.) head as shown in Fig. 1. The vane and jig were set on selected angular graduations and the output of the pitch vane channel was displayed on O.L. D.V.M.

2.6 Sideslip Vane

The jig was repositioned on the sideslip vane and the above procedure was repeated.

2.7 Airspeed (Nose Boom Pitot Static)

The pitot was covered with a sleeve, and an airspeed indicator (A.S.I.) and pump were connected as shown in Fig. 2. The pitot was pressurized and at a range of airspeeds the airspeed differential pressure transducer channel output was displayed on the Q.L. D.V.M.

2.8 Barometric Altitude

The static pressure tubing connecting the front and rear pressure transducers was temporarily removed from the rear transducer and sealed. The static pressure holes were covered with the sleeve and an altimeter and pump connected as shown in Fig. 3. A suction was applied and at several altitudes the absolute pressure transducer channel output was recorded and displayed on Q.L. D.V.M. The atmospheric pressure at the aerodrome level Q.F.E. was also recorded.

2.9 Airspeed (Trailing Pitot Static)

The trailing probe pitot was covered with a sleeve and an A.S.I. and pump were connected as in Fig. 2. A pressure was applied and at a range of airspeeds the trailing P.S. pressure transducer output was recorded and displayed on the Q.L. D.V.M.

2.10 Static Pressure (Differential)

The sleeve was pushed over the trailing P.S. probe to cover the static holes and an A.S.I. and pump were connected as shown in Fig. 4. A suction was applied, and at several airspeeds the output of the differential (statics) transducer was recorded and displayed on the Q.L. D.V.M.

2.11 Pitch Attitude

The pitch gyro was rotated in its cradle and locating pins inserted at several calibration check points. At each point the pitch attitude linvar channel output was displayed on the Q.L. D.V.M.

2.12 Roll Attitude

A similar procedure was used for the roll gyro to that used for the pitch gyro.

2.13 Longitudinal Acceleration

The accelerometer was removed from the triaxial mount and was held and rotated in 90° steps so that its sensitive axis was subjected to 1g, 0 and -1g in turn. The longitudinal acceleration channel was recorded and displayed on the Q.L. D.V.M.

2.14 Lateral Acceleration

The lateral accelerometer was subjected to the same test as the longitudinal accelerometer.

2.15 Vertical Acceleration

The vertical accelerometer was subjected to the same test as the longitudinal accelerometer.

2.16 Cable Angle Longitudinal

The sonar ball was lowered from the funnel and allowed to rest on the ground so that the tension was removed from the cable. The guide fork was then pushed from the fore to aft extreme and at a range of positions an inclinometer was used to measure the fork angle and the Q.L. D.V.M. used to record the output of the longitudinal cable angle channel. A calibration was also made of the indicator on the instrument panel at set positions against the recorded output.

2.17 Cable Angle Lateral

A similar procedure to the longitudinal cable angle was repeated with the guide fork moved from the port to starboard extreme.

2.18 Radio Altimeter (Raw and Smooth)

A reflector was placed on the ground beneath the Radio Altimeter (Rad. Alt.) antenna in such a position that the Rad. Alt. beam was deflected and transmitted forward parallel to the ground. A vehicle parked at selected known distances forward of the aircraft provided the necessary target during the recording of both the Rad. Alt. raw and smooth channels. A switch on the Rad. Alt. indicator selected the raw or smooth mode.

3. CHANNELS CALIBRATED WITH ENGINES OPERATING AND ROTOR BLADES SPREAD

3.1 Torque Engine No. 1 (Left Hand Engine)

With engine no. 2 at idle the collective stick was raised to place a loading on no. 1 engine. A number of torque levels for no. 1 engine were established using the torque meter on the aircraft instrument panel and for each of these, the eng. 1 torque channel output was recorded and displayed on Q.L. D.V.M.

3.2 Torque Engine No. 2

A similar procedure to Eng. No. 1 was repeated for Eng. No. 2, with No. 1 engine at idle.

3.3 Rotor Speed

The rotor R.P.M. was varied over a range indicated as a percentage of N_r by the aircraft panel meter. At selected points the rotor R.P.M. tachometer channel was recorded and displayed. The higher readings N_r>110% were calibrated during autorotation.

4. CHANNELS CALIBRATED IN FLIGHT

4.1 Doppler Longitudinal

4.1.1 Low speed

In still air conditions a vehicle was driven along the side of the runway at a constant speed. The aircraft was flown behind the vehicle and maintained a constant speed and separation distance while the speed of the vehicle and the Doppler long channel were recorded. A stop watch also measured the time of flight over a known distance. This was then repeated for a range of vehicle speeds.

4.1.2 High speed

This procedure was adopted when the aircraft's ground speed was to exceed the maximum speed of the vehicle. The aircraft was timed with a stop watch flying between two marks on the runway a fixed distance apart while the Doppler long was again recorded. The procedure was repeated at a range of I.A.S. in still air conditions.

4.2 Doppler Lateral

A similar procedure to that used for the low speed Doppler (long) was used but the aircraft was flown sideways behind the pace vehicle while the measurements were made (Ref. Fig. 5).

4.3 Radio Altimeter (Raw and Smooth)

The aircraft was established in stable flight over level terrain. At a range of altitudes indicated on the Radio Altimeter in both the raw and smooth modes the recordings of Rad. Alt. were made.

4.4 Yaw Attitude

The aircraft was set on a number of compass headings indicated by the pilots remote gyro compass (B.D.H.I.). At each of these headings the yaw attitude channel output was displayed and noted. In some instances the headings were obtained in the hover and in others the aircraft was taxied around. A calibration check was required on this channel for each flight after the pilots remote compass and the master indicator were synchronised.

4.5 Yaw Rate

The aircraft was hovered at a suitable altitude in still air conditions. From the hover a spot turn was entered and when a constant rate of turn was reached the time and angular displacement were measured. A recording was made of the yaw rate channel. Steady output voltages from the yaw rate channel could not be obtained during flight so the transcription process quick look system was used to plot a graph with an x-y plotter and a mean value was estimated from the graph. Several rates of turn to both port and starboard were recorded.

4.6 Ball Depth

The aircraft was flown over the sea and hovered into wind and the ball lowered into the water. As this channel did not provide satisfactory data, a voice recording on the flight tape of the depth indicated on the pilots panel meter was made.

4.7 Cable Length

Under the same conditions as for ball depth, a voice recording of the cable length indicated on the pilots panel meter was made on the flight tape.

5. CHANNELS NOT CALIBRATED IN AIRCRAFT

5.1 Roll Rate

It was impossible to establish a constant roll rate of any duration so no calibration of this channel was made. However the roll gyro manufactures data and the amplifier gain was used to provide a calibration of this channel.

5.2 Pitch Rate

Again it is impossible to establish a constant pitch rate of any duration so the calibration was made from the pitch gyro-manufactures data and measured amplifier gain.

5.3 Outside Air Temperature

The platinum resistance temperature sensor was placed in a **beaker** of water in the laboratory and connected as an arm to its bridge amplifier. The water temperature was varied over the expected range of the inflight outside air temperatures. At a number of points the water temperature and the bridge amplifier output were measured.

6. COMPARISON OF AIRBORNE AND TRANSCRIPTION QUICK LOOK SYSTEMS OUTPUTS

The output of the transcription process Q.L. system was in the range +5 volts to -5 volts, +5V corresponding to digital count 0 and -5 volt digital count of 4095. The digital to analogue converter used in the airborne Q.L. system gave an output in the range 0 to -10 volts. There was an offset introduced such that 0 volts output from the transcription Q.L. corresponded to -4.93 volts on the airborne Q.L. system.

7. CONCLUSION

This Memorandum describes and tabulates calibration procedures used during the Sea King mathematical model flight validation trials in July-August 1979. The purpose of this document is to provide a convenient record of the calibration of all channels for use in the analysis of the recorded data.

TEXT DESCRIPTION	TABLE NO.	D.A.S. CHANNEL NO.
Cyclic Pitch	1	1,5
Cyclic Roll	2	2,6
Collective Pitch	3	3,7
Yaw Pedal	4	16,8
Pitch Vane	5	4
Sideslip Vane	5	9
Airspeed (Boom)	6	23
Barometric Altitude	7	26
Airspeed (Trailing P.S.)	6	32 (ii)
Static Pressure Difference	8	31 (ii)
Pitch Attitude	9	15
Roll Attitude	10	10
Accelerator Longitudinal	11	12

CROSS INDEX CALIBRATION DATA TABULATION - D.A.S. CHANNEL NO.

TEXT DESCRIPTION	TABLE NO.	D.A.S. CHANNEL NO.
Acceleration Lateral	11	13
Acceleration Vertical	11	14
Cable Angle Longitudinal	12	19
Cable Angle Lateral	13	20
Radio Altimeter Raw & Smooth	14,15	24,25
Torque Eng. No. 1	16	29
Torque Eng. No. 2	16	18 (ii)
Rotor Speed	17	30
Doppler Longitudinal Low Speed	18	21
Doppler Longitudinal High Speed	19	21
Doppler Lateral	20	22
Yaw Attitude	21	18 (i)
Yaw Rate	22	17
Ball Depth	-	31 (i)

CROSS INDEX CALIBRATION DATA TABULATION - D.A.S. CHANNEL NO.

TEXT DESCRIPTION	TABLE NO.	D.A.S. CHANNEL NO.
Cable Length	-	32 (i)
Roll Rate	23	11
Pitch Rate	23	27
Outside Air Temperature	24	28

CROSS INDEX CALIBRATION DATA TABULATION - D.A.S. CHANNEL NO.

FOR-AFT CYCLIC STICK ANGLE (DEG.)		FOR-AFT CYCLIC LINVAR CHANNEL OUTPUT (VOLTS)	DISPLACEMENT AUX. SERVO FOR-AFT PUSH PULL ROD (INCHES)	AUX. SERVO FOR-AFT PUSH PULL ROD CHANNEL OUTPUT (VOLTS)	ROTOR BLADE ANGLE FOR-AFT JACK (DEG.)
		COLLECTIVE LEVER FULLY DOWN			
STICK FULL FORWARD	43°15	-9.19	7.75	-0.72	-8
	46	-8.68	7.81	-1.15	-6.4
	49	-8.08	7.94	-1.85	-4.3
	52	-7.41	8.09	-2.63	-2.0
	55	-6.73	8.28	-3.46	+0.4
	58	-6.04	8.47	-4.33	+2.8
	61	-5.34	8.66	-5.29	+5.2
	64	-4.68	8.81	-6.01	+7.4
	67	-3.98	9.0	-6.84	+9.7
	70	-3.27	9.19	-7.71	+11.9
	73	-2.57	9.34	-8.53	+14.1
	76	-1.84	9.53	-9.32	+16.3
STICK FULL AFT	78°15	-1.31	9.66	-9.89	+17.7
		COLLECTIVE LEVER FULLY RAISED			
STICK FULL FORWARD		-9.20	7.72	-0.72	+1.5
STICK FULL AFT		-1.31	9.63	-9.90	+26.1

TABLE 1. CALIBRATION OF CYCLIC PITCH CONTROL

LATERAL CYCLIC STICK ANGLE (DEG.)	CYCLIC ROLL LINVAR CHANNEL OUTPUT (VOLTS)	DISPLACEMENT AUX. SERVO LATERAL PUSH PULL ROD (INCHES)	AUX. SERVO LATERAL PUSH PULL ROD CHANNEL OUTPUT (VOLTS)	ROTOR BLADE ANGLE PORT LATERAL JACK (DEG.)
	COLLECTIVE	LEVER FULLY DOWN		
STICK FULLY TO PORT 105°20	-1.72	15.59	-2.27	-1.1
102	-2.46	15.75	-3.04	0.5
97	-3.64	16.88	-4.31	3.0
92	-4.81	16.63	-5.62	5.5
87	-5.88	16.38	-6.63	7.5
82	-7.04	16.06	-7.81	10.0
77	-8.22	17.19	-8.96	12.2
STICK FULLY TO STB. 72	-9.29	17.44	-9.94	14.2
	COLLECTIVE	LEVER FULLY RAISED		
STICK FULLY TO PORT	-1.74	15.59	-2.27	9.3
STICK FULLY TO STB.	-9.27	17.63	-9.93	24.0

TABLE 2. CALIBRATION OF CYCLIC ROLL CONTROL.

COLLECTIVE LEVER ANGLE (DEG.)		COLLECTIVE LEVER TRANSDUCER CHANNEL OUTPUT (VOLTS)	DISPLACEMENT AUX. SERVO COLLECTIVE PUSH PULL ROD (INCHES)	AUX. SERVO COLLECTIVE PUSH PULL ROD CHANNEL OUTPUT (VOLTS)	ROTOR BLADE ANGLE FOR-AFT JACK (DEG.)
LEVER FULLY DOWN	$150^{\circ}35$	-9.14	7.56	-1.40	6.2
	150	-8.83	7.66	-1.66	6.5
	145	-6.69	8.32	-3.83	10.2
	140	-4.46	9.0	-6.03	13.5
	135	-2.21	9.69	-8.26	17.0
LEVER FULLY RAISED	$132^{\circ}35$	-0.99	9.97	-9.26	18.4

TABLE 3. CALIBRATION OF COLLECTIVE CONTROL.

YAW PEDAL DISPLACEMENT (CM.)	YAW PEDAL CROSS BAR TRANSDUCER CHANNEL OUTPUT (VOLTS)	DISPLACEMENT AUX. SERVO YAW PUSH PULL ROD (INCHES)	AUX. SERVO YAW PUSH PULL ROD CHANNEL OUTPUT (VOLTS)	TAIL ROTOR BLADE ANGLE (DEG.)
COLLECTIVE LEVER MID POSITION				
LEFT PEDAL FULLY FORWARD 66.0	-9.10	9.69	-9.52	23.8 BOT. 22.7 TOP
64.0	-8.31	9.66	-9.56	23.8 22.7
60.0	-6.54	9.19	-7.45	19.1 18.2
55.0	-4.297	8.47	-4.40	6.2 5.1
50.0	-2.13	7.75	-1.44	-7.5 -8.7
RIGHT PEDAL FULLY FORWARD 47.5	-1.18	7.66	-1.39	-7.5 -8.7
COLLECTIVE LEVER FULLY DOWN				
RIGHT PEDAL FULLY FORWARD	-1.65	8.03	-2.67	-7.5 -9.0
LEFT PEDAL FULLY FORWARD	-9.80	9.99	-9.94	23.8 22.8
COLLECTIVE LEVER FULLY RAISED				
RIGHT PEDAL FULLY FORWARD	-1.14	7.59	-0.97	-4.2 -5.5
LEFT PEDAL FULLY FORWARD	-8.37	9.31	-8.15	23.8 22.8

TABLE 4. CALIBRATION OF YAW PEDAL CONTROL.

PITCH VANE ANGLE (DEG.)	PITCH CHANNEL OUTPUT (VOLTS)	SIDESLIP VANE ANGLE (DEG.)	SIDESLIP CHANNEL OUTPUT (VOLTS)
NOSE UP +45	-2.24	SIDESLIP +45 TO STB.	-2.19
+30	-3.05	+30	-3.00
+15	-3.86	+15	-3.82
0	-4.69	0	-4.65
NOSE DOWN -15	-5.51	-15	-5.46
-30	-6.34	-30	-6.30
-45	-7.16	-45	-7.11

TABLE 5. CALIBRATION OF PITCH AND SIDESLIP VANES.

TEST SET I.A.S. (M.P.H.)	BOOM PROBE AIRSPEED CHANNEL OUTPUT (VOLTS)	TRAILING PROBE AIRSPEED CHANNEL OUTPUT (VOLTS)
0	-9.29	-8.92
40	-8.68	-8.47
60	-7.78	-7.87
80	-6.58	-7.03
100	-4.48	-5.84
120	-2.63	-4.35
130	-1.47	-3.40
0	-9.31	-8.93

TABLE 6. CALIBRATION OF AIRSPEED (BOOM AND TOWED PROBE).

TEST ALTIMETER HEIGHT ABOVE AERODROME (FEET)	BAROMETRIC ALTITUDE CHANNEL OUTPUT (VOLTS)	Q.N.H. (m.b.)	
0	-2.47	1021	FLIGHT 1
1000	-3.79		
2000	-5.10		
3000	-6.38		
4000	-7.53		
5000	-8.72		
0	-2.49		
0	-3.15	1008	FLIGHT 2
1000	-4.56		
2000	-5.83		
3000	-7.11		
4000	-8.26		
5000	-9.39		
0	-3.23		
0	-3.10	1020	FLIGHT 3 & SUBSEQUENT FLIGHTS
1000	-4.36		
2000	-5.65		
3000	-6.84		
4000	-8.03		
5000	-9.14		
0	-3.11		

TABLE 7. CALIBRATION OF BAROMETRIC ALTITUDE.

TEST SET A.S.I. (M.P.H.)	DIFFERENCE BETWEEN ABSOLUTE PRESSURES-CHANNEL OUTPUT (VOLTS)		
	4/8/79	15/8/79	
0	-4.96	-5.00	
40	-3.77	-3.60	
60	-2.09	-2.00	
80	-0.06	-0.06	80 M.P.H. AND ABOVE OUT OF RANGE OVERLOAD
90	-0.06		
70	-0.97	-0.84	
60		-1.97	
0	-4.96	-4.96	

TABLE 8. CALIBRATION OF STATIC DIFFERENCE (POSITION ERROR)

PITCH ATTITUDE PLATFORM ANGLE (DEGREES)		PITCH ATTITUDE CHANNEL OUTPUT (VOLTS)		
		FLIGHT 1		FLIGHT 2 & SUBSEQUENT
	24			-2.39
CLIMB	20	-3.25	INPUT	
CLIMB	15	-3.17	AMPLITUDE	
CLIMB	14½		OVERLOAD	-3.35
CLIMB	12½	-3.11		
CLIMB	10	-3.12		
CLIMB	7½	-3.51		
CLIMB	5	-4.06		
CLIMB	4½			-4.47
	2½	-4.51		
	0	-5.05		
DIVE	-½			-5.10
DIVE	-5	-5.98		
DIVE	-5½			-5.71
DIVE	-10	-6.73		
DIVE	-12½	-6.73	INPUT	
DIVE	-15	-6.67	AMPLITUDE	
DIVE	-15½		OVERLOAD	-6.85
DIVE	-20	-6.59		
DIVE	-21½	-6.54		-7.50

TABLE 9. CALIBRATION OF PITCH ATTITUDE.

	ANGLE OF ROLL (DEGREES)	ROLL ATTITUDE CHANNEL OUTPUT (VOLTS)
	0	-4.87
ROLL TO STB.	+8	-3.93
	+24	-2.07
ROLL TO PORT	-8	-5.90
	-24	-7.77

TABLE 10. CALIBRATION OF ROLL ATTITUDE.

SENSITIVE AXIS POSITION	LONGITUDINAL ACCELEROMETER CHANNEL OUTPUT (VOLTS)	LATERAL ACCELEROMETER CHANNEL OUTPUT (VOLTS)	VERTICAL ACCELEROMETER CHANNEL OUTPUT (VOLTS)
HORIZONTAL	-4.91	-4.94	-4.95
VERTICAL (CONNECTOR UPWARDS)	-4.43	-4.44	-4.44
VERTICAL (CONNECTOR DOWNWARDS)	-5.42	-5.44	-5.44

TABLE 11. CALIBRATION OF TRIAXIAL ACCELEROMETERS.

CABLE FORK ANGLE (DEGREES)		OUTPUT OF LONGITUDINAL CABLE ANGLE CHANNEL (VOLTS)	PILOTS INDICATOR POSITION	OUTPUT OF LONGITUDINAL CABLE ANGLE CHANNEL (VOLTS)
INCLINOMETER READING	DEFLECTION			
126	0	-4.80	CENTRE	-4.84
124	+2	-5.77	FULL FORWARD	-9.92
122	+4	-6.64	FULL AFT	-0.62
120	+6	-7.52	3rd DIV FOR	-9.30
118	+8	-8.39	2nd DIV FOR	-7.80
126	0	-4.82	1st DIV FOR	-6.64
128	-2	-3.96	FORWARD CIRCLE	-5.87
130	-4	-3.15	CENTRE	-4.81
132	-6	-1.90	AFT CIRCLE	-3.75
134	-8	-1.43	1st DIV AFT	-2.81
			2nd DIV AFT	-1.66
			3rd DIV AFT	-0.80
			FULL AFT	-0.69

TABLE 12. CALIBRATION OF LONGITUDINAL CABLE ANGLE.

CABLE FORK ANGLE (DEGREES)	OUTPUT OF LATERAL ANGLE CHANNEL (VOLTS)	PILOTS INDICATOR POSITION	OUTPUT OF LATERAL CABLE ANGLE CHANNEL (VOLTS)
0	-6.33	CENTRE	-6.27
2	-6.73	FULL PORT	-9.92
4	-7.05	FULL STB.	-2.61
6	-7.36	STB. CIRCLE	-5.92
8	-7.72	1st DIV STB.	-5.58
10	-8.10	2nd DIV. STB.	-5.27
0	-6.32	3rd DIV STB.	-4.94
-2	-6.00	PORT CIRCLE	-6.52
-4	-5.62	1st DIV. PORT	-6.89
-6	-5.25	2nd DIV. PORT	-7.23
-8	-4.92	3rd DIV. PORT	-7.43
-10	-4.59		

TABLE 13. CALIBRATION OF LATERAL CABLE ANGLE.

REFLECTOR TO VEHICLE DISTANCE (FT.)	RAD. ALT. RAW ALTITUDE (FT.)	RAD. ALT. RAW CHANNEL OUTPUT (VOLTS)	RAD. ALT. SMOOTH ALTITUDE (FT.)	RAD. ALT. SMOOTH CHANNEL OUTPUT (VOLTS)
20	12	-4.81	14	-4.79
40	36	-4.60	34	-4.62
60	55	-4.43	55	-4.43
80	76	-4.25	76	-4.25
100	97	-4.06	97	-4.06
120	118	-3.87	118	-3.90
140	138	-3.68		
163	160	-3.50		

TABLE 14. GROUND CALIBRATION OF RAD. ALT. SMOOTH AND RAW.

RADIO ALTIMETER RAW ALTITUDE (FT.)	RADIO ALTIMETER RAW CHANNEL OUTPUT (VOLTS)	RADIO ALTIMETER SMOOTH CHANNEL OUTPUT (VOLTS)
5	-4.88	-4.87
20	-4.74	
40	-4.58	-4.37
60	-4.39	
80	-4.21	-3.78
100	-4.04	
200	-3.06	-1.83
300	-2.25	-0.5
400	-1.27	-0.06
500	-0.35	-0.06

TABLE 15. CALIBRATION OF RAD. ALT. SMOOTH & RAW.

ENGINE # 1 TORQUE METER READING (%)	OUTPUT OF ENG. # 1 TORQUE CHANNEL (VOLTS)	ENGINE # 2 TORQUE METER READING (%)	OUTPUT OF ENG. # 2 TORQUE CHANNEL (VOLTS)
32	-6.70		
40	-6.20	40	-6.30
50	-5.54	50	-5.60
60	-4.94	60	-5.00
70	-4.28	70	-4.34
80	-3.70	79	-3.77
90	-3.10		

TABLE 16. CALIBRATION OF ENGINE TORQUES.

ROTOR SPEED ($\% N_r$)	ROTOR SPEED CHANNEL OUTPUT (VOLTS)
88	-0.60
90	-1.00
92	-1.35
94	-1.80
96	-2.25
98	-2.69
100	-3.10
102	-3.53
104	-3.97
106	-4.37
108	-4.83
109	-5.04
HIGHER R.P.M. OBTAINED DURING AUTOROTATION	
114-115	-6.5

TABLE 17. CALIBRATION OF ROTOR SPEED.

VEHICLE SPEED (K.P.H.)	TIME (SECS.)	DISTANCE (FT.)	OUTPUT OF LONGITUDINAL DOPPLER CHANNEL (VOLTS)		GROUND SPEED (KTS.)
			A.F.C.S. ON	A.F.C.S. OFF	
-30			-5.50	-5.46	
-15			-5.14	-5.18	
20	59.2	1000	-4.55	-4.53	10.02
40	29.6	1000	-4.19	-4.18	20.04
60	19.4	1000	-3.77	-3.85	30.59
80	30	2000	-3.36	-3.37	39.53

TABLE 18. CALIBRATION OF LONGITUDINAL DOPPLER (LOW SPEED).

DOPPLER VELOCITY (KT.)	DISTANCE (FT.)	TIME (SECS.)	GROUND SPEED (KTS.)	OUTPUT OF LONGITUDINAL DOPPLER CHANNEL (VOLTS)
60 AFCS OFF	3000	31.5	56	-2.86
70 AFCS OFF	"	26.5	67	-2.48
80 AFCS OFF	"	18.0	76	-2.12
90 AFCS OFF	"	21.0	85	-1.80
100 AFCS OFF	"	19.0	94	-1.51
110 AFCS ON	"	17.0	104	-1.01

TABLE 19. CALIBRATION OF LONGITUDINAL DOPPLER (HIGH SPEED).

VEHICLE SPEED (K.P.H.)	GROUND SPEED (KTS.)	LATERAL DOPPLER CHANNEL OUTPUT (VOLTS)	
		A.F.C.S. ON	A.F.C.S. OFF
-30	-15	-5.90	-6.07
-15	-7.5	-5.46	-5.44
15	7.5	-4.41	-4.45
30	15	-3.88	-3.95

TABLE 20. CALIBRATION OF LATERAL DOPPLER.

GYRO COMPASS INDICATOR HEADING (DEGREES)	YAW ATTITUDE CHANNEL OUTPUT (VOLTS)		
	FLIGHT 1	FLIGHT 2	FLIGHT 3
360	-4.79		
30	-5.61		
60	-6.40		
90	-7.24	-6.16	-5.97
120	-8.06		
150	-8.89		
180	-9.74	-8.68	-8.49
210	-0.64		
240	-1.48		
270	-2.31	-1.26	-1.07
300	-3.11		
330	-3.97		
360	-4.79	-3.68	-3.52

TABLE 21. CALIBRATION OF YAW ATTITUDE.

TIME OF ROTATION FOR 180 DEGREES (SECS.)		RATE OF TURN (DEG./SEC.)	MEAN OUTPUT YAW RATE CHANNEL (VOLTS)
56	TO STB.	3.2	0.35
32	TO STB.	5.6	0.7
16	TO STB.	11.3	1.40
66	TO PORT	2.7	-0.55
36	TO PORT	5.0	-1.0
15	TO PORT	12.0	-1.7

TABLE 22. CALIBRATION OF YAW RATE CHANNEL.

ROLL RATE GYROSCOPE CHANNEL	PITCH RATE GYROSCOPE CHANNEL
1 RAD/SEC. GIVES 5V D.C.	1^{o}/SEC. GIVES 0.2V (R.M.S.)
1^{o}/SEC. 87.26 mV	SYNCHRONOUS DEMODULATER OUTPUT 5V D.C. FOR 7V (R.M.S.) INPUT
CONDITIONING AMPLIFIER GAIN = 0.99	1^{o}/SEC. = 0.2 X 5/7 = 0.143 V
1^{o}/SEC. = 86.39 mV	= 143 mV
OR 1 VOLT = 11.58^{o}/SEC.	OR 1 VOLT = 7^{o}/SEC.

TABLE 23. CALIBRATION FACTORS FOR ROLL & PITCH RATES

PLATINUM SENSOR TEMPERATURE (DEGREES CELSIUS)	TEMPERATURE BRIDGE AMPLIFIER OUTPUT (VOLTS)
-10	-4.95
-5	-3.93
0	-2.90
+5	-1.90
+10	-0.88
+15	0.16
+20	1.17
+25	2.20
+30	3.22
+35	4.22
+40	5.25

TABLE 24. CALIBRATION OF O.A.T. SENSOR AND AMPLIFIER.

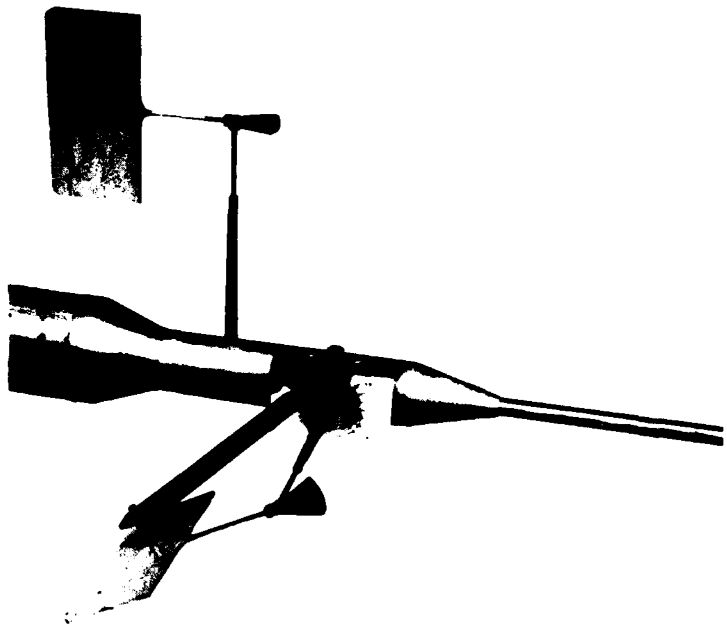

FIG.1 JIG USED IN CALIBRATION OF PITCH & SIDESLIP CHANNELS

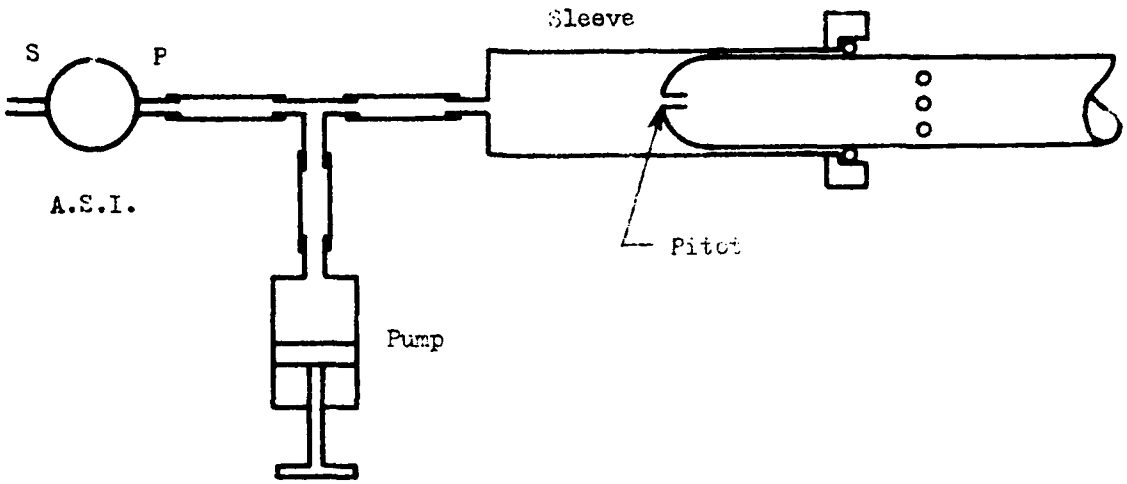

FIG.2 CONNECTION DIAGRAM FOR CALIBRATING DYNAMIC PRESSURE
(AIRSPEED) CHANNEL

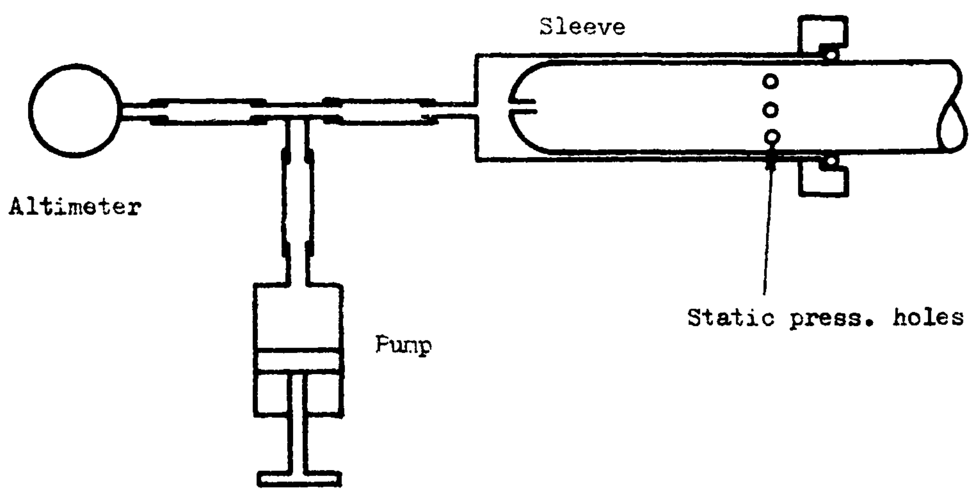

FIG.3 CONNECTION DIAGRAM FOR CALIBRATING ABSOLUTE PRESSURE
(BAR. ALT.) CHANNEL

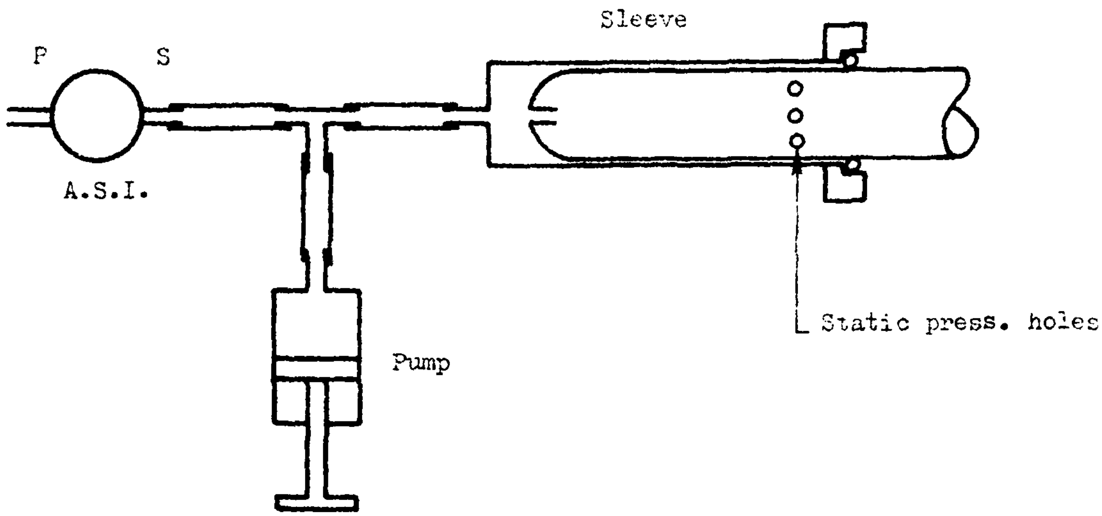

FIG.4 CONNECTION DIAGRAM FOR CALIBRATING DIFFERENTIAL STATIC PRESSURE CHANNEL

FIG.5 CALIBRATION OF LATERAL DOPPLER CHANNEL

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